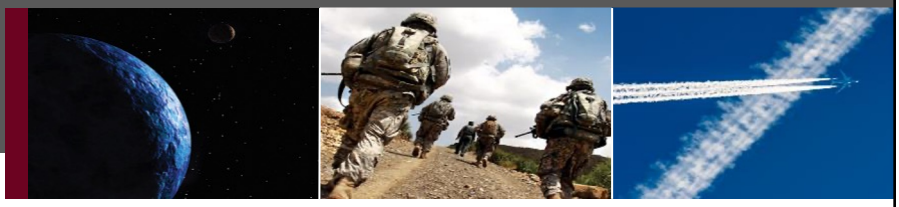
CIMdata's PLM Road Map™ @ GPDIS 2022

Digital Transformation and PLM – a call for PLM professionals to re-define and re-position the benefits and value of PLM

September 27



Benefits and Challenges of a Digital Twin Approach to Additive Manufacturing

Brian Kopacz

MOOG

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Agenda

- Objectives:
  - Help inform PLM community of some challenges and opportunities within AM to foster innovation and solutions which enable AM for A&D
  - Engage with others who may be working on similar challenges in AM in order to discuss lessons learned and best practices

- Intro to Moog AMC
- Overview of AM process
- Data of AM
- Towards a digital twin of AM
- Benefits and Challenges

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Moog Inc.

- Founded in 1951 by Bill Moog
- Headquarters in East Aurora, NY
  - Over 300-acre campus
- Global company
  - 26 countries
- Over 12,000 employees worldwide
- $2.9 billion in revenue (FY 2021)
- Aerospace, defense, industrial
- Precision control systems solutions and component provider

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Metal Additive at Moog

ATC
ADVANCED TECHNOLOGY CENTER

2013
Established Advanced Technology Center (ATC)
To Progress Additive Research and Development

2015
Acquired Linear AMS
Additive Service Bureau Capabilities

AMC
ADDITIVE MANUFACTURING CENTER

2018
Established Additive Manufacturing Center (AMC)
To Develop Additive Production Capabilities

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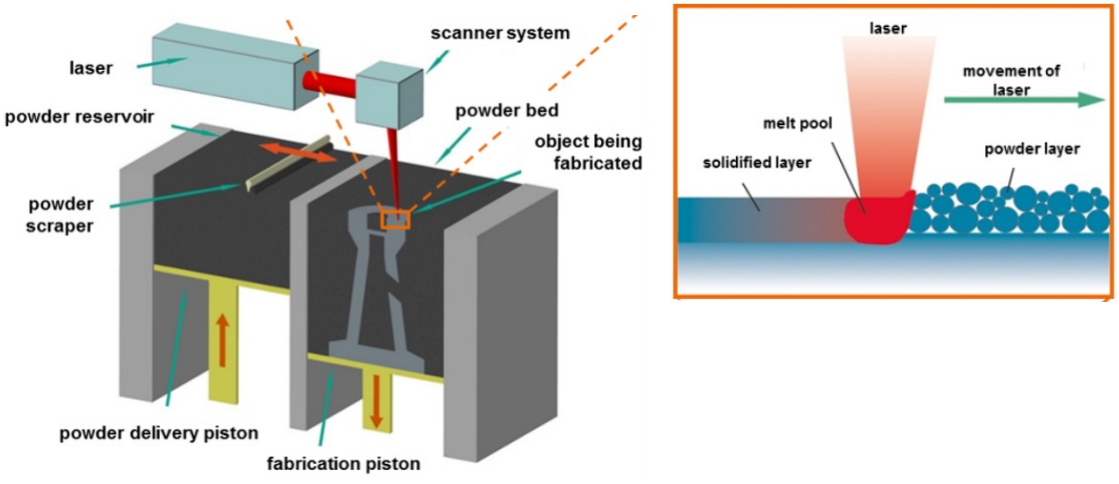
How Does LPBF Work?



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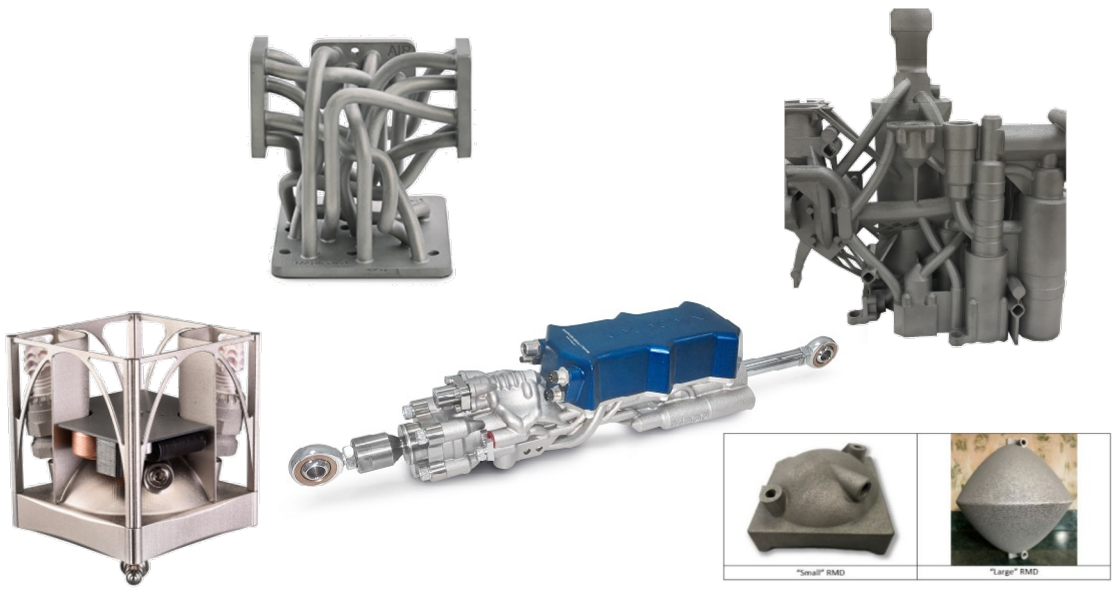
Examples of Moog AM Hardware



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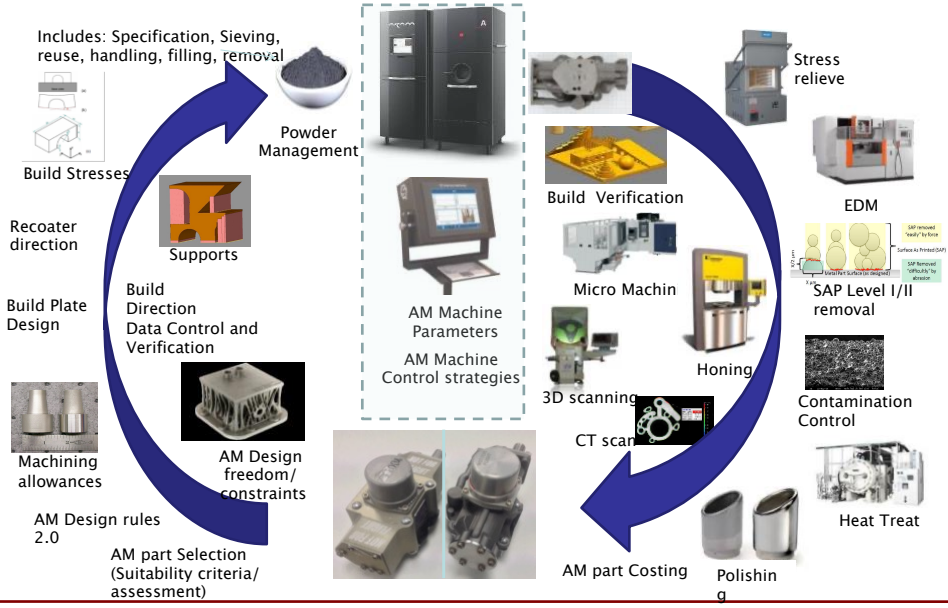
AM is more than just the AM machine:



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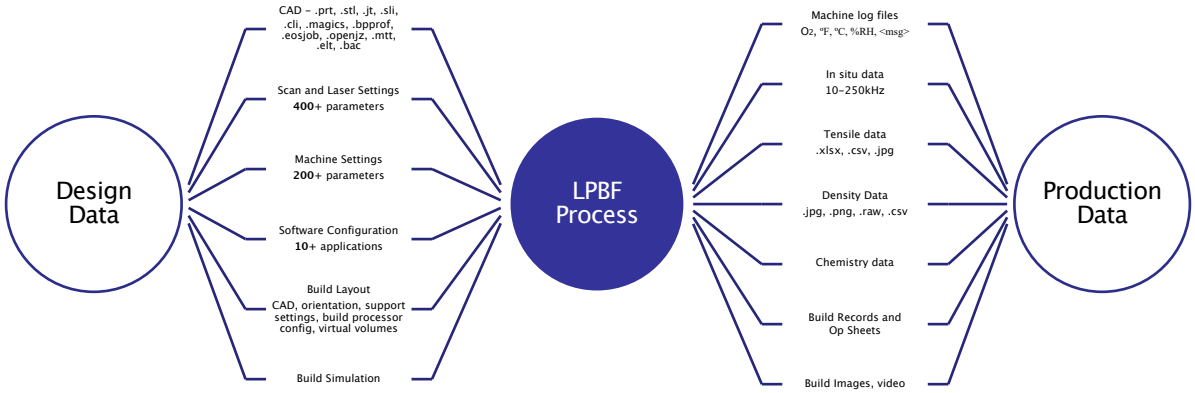
AM Data – Digital Threads

- LPBF contains ~10^3 process variables [design data] and perceptive parameters [production data]



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Digital Thread – Design Data

- Managing the product definition digital thread is key
- This can be complex for additive manufacturing
- It is a requirement for A&D AM

NASA STD 6030

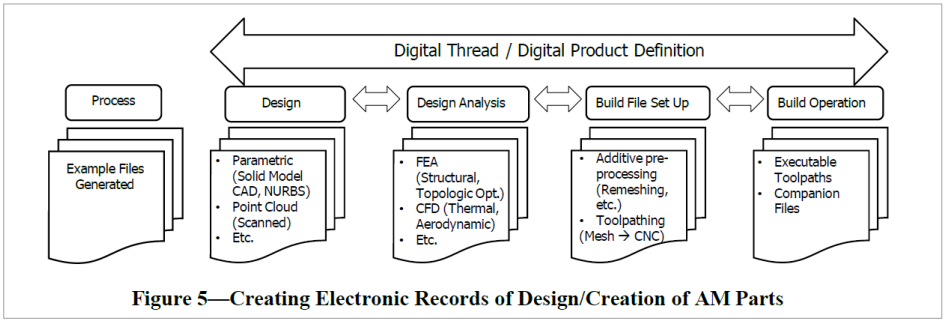

Figure 5—Creating Electronic Records of Design/Creation of AM Parts

AMS700

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Digital Thread – Production Data

- Managing the production data digital thread is equally as crucial
- Each machine is a 'foundry'
- Moog has published material properties using MMPDS methods
- Moog supports customer in material development as required

Define the Process → Characterize Material → Control the Process → Monitor Material

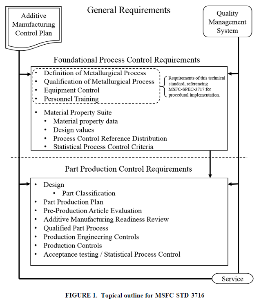
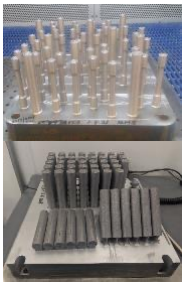
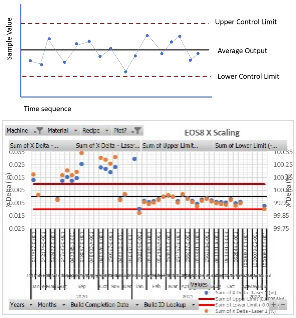
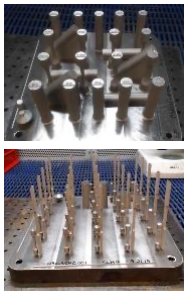


FIGURE 1. Topical outline for MSFC STD 3716







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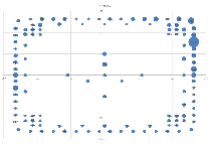
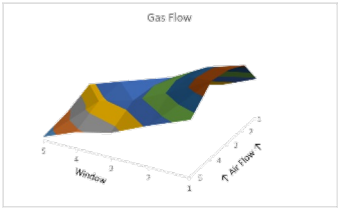
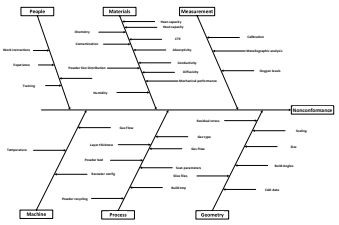
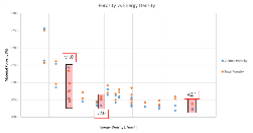
Digital Thread – Production Data

- Understand cause and effect relationships
- Gain insights
  - Position dependence / keep out zones
  - KPV's
  - Material (chemistry / PSD) drift
  - Machine (calibration) drift
  - Material performance
  - Parameter optimization
  - Active parameter control
  - Employ machine learning on data sets









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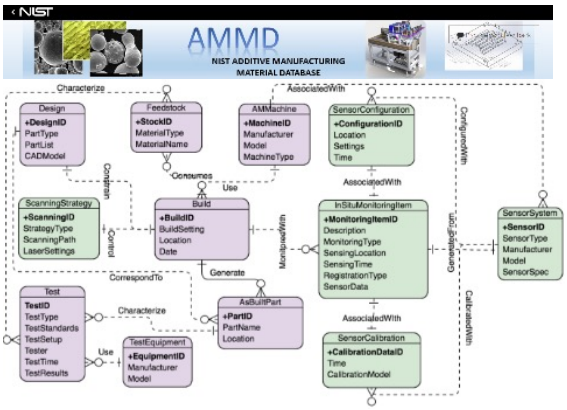
Managing the Digital Thread

- NIST AMMD – project to develop schema for AM data
  - Utilizes NIST Material Data Curation System (MDCS)
  - .xml schema is 891 lines of code
- There are also companies that provide versions of this as a solution



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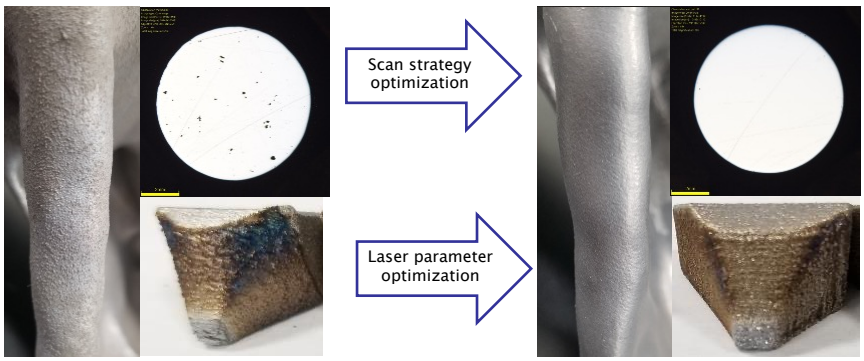
AM Digital Threads at Moog

- Product definition digital thread is managed the same as other PLM data
- Organically grown production database
- Leveraging data to improve output quality
- New and enhanced software and simulation leads to better models



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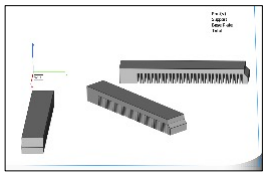
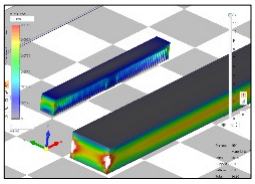
Additive Manufacturing Digital Twin



Model

Predict

Inspection data
Design feedback



Build
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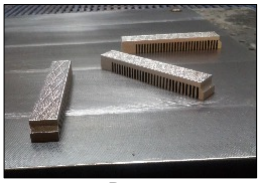
Build file
Machine
settings

Build

Physical Build

In situ data
Build artifacts

Inspect



Part

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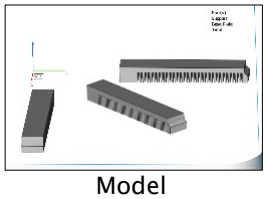
Additive Manufacturing Digital Twin



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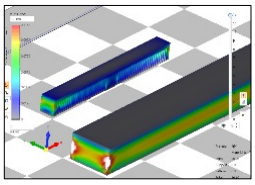

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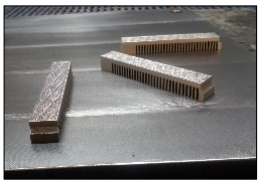

Part

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Benefits and Challenges

- Benefits
  - Single source of truth
  - Configuration management
  - Data reuse
  - Quality control
  - Quality improvement
  - New insights
- Challenges
  - Many different types of data
  - Deciding which data to collect
  - Collecting data
  - Data integrity
  - Data commonality and interoperability
- AM for Aerospace requires robust product life cycle management
- Incorporating AM production data into PLM creates a closed loop data ecosystem which improves the AM process significantly
- Systems and tools are required to manage large numbers of variables and large quantities of data

Questions

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